RADCLIFFE COLLEGE

The Mary Ingraham Bunting Institute
Radcliffe Research and Study Center
34 Concord Avenue, Cambridge, Massachusetts 02138 (617) 495-8212

THE MARY INGRAHAM BUNTING INSTITUTE OF RADCLIFFE COLLEGE

TECHNICAL REPORT
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SCIENCE SCHOLARS PROGRAM
9/1/92 - 8/31/93

N00014-89-J-3112

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Principal Investigator
and Linda Eisenmann, Assistant Director,
Bunting Institute

This technical report for the 1993 Science Scholars Program at the Bunting Institute of Radcliffe College describes the 1993 Science Scholars who were fellows of the Bunting Institute during 1992-1993 academic year. It describes the program and the fellows, the scholars' evaluations of the fellowship year, highlights of the program year, and issues involved in the program. The report then describes the selection process for the 1994 Science Scholars. Appendices contain the scholars' publications, evaluations, reports and other pertinent materials.

1993 Program

Background of the Program

The Office of Naval Research supported nine scholars with eight fellowships during the fellowship year September 1, 1992 to August 31, 1993. In 1992, the program appointments had been shifted to coincide with the academic rather than the fiscal calendar. Therefore, this grant report covers the period of the fellowship year.

As in other years, two fellows split one of the stipends. Aquatic ecologist Nancy Butler received a job offer which freed her to accept only one term at the Bunting Institute. She held the fellowship in the fall term only. Constance Royden, a neuroscientist, was able to accept the fellowship for the spring semester and summer.

In 1993 the stipend per fellowship was $30,700, with an additional $3000 available to each fellow to cover research-related expenses. Each scholar also received an office at the Bunting Institute and officer's privileges at Harvard University which allow access to all libraries and other resources at Harvard and Radcliffe.

Most of the 1993 scholars were laboratory-based, and the majority affiliated with Harvard University departments or laboratories (six scholars). Of the other three fellows, two affiliated at the Massachusetts Institute of Technology, and one moved with her laboratory director from MIT to Wellesley College.

The 1993 scholars, along with their initial affiliations, included:

Bonnie Berger, Computer Science, Massachusetts Institute of Technology, "Efficient Parallel Algorithms"

Nancy M. Butler, Aquatic Ecology, Great Lakes Environmental Research Laboratory, "Nitrogen Isotope Fractionation in Marine Zooplankton: Effects of Trophic Status, Food Quality, and Development State"

Rosanne DiStefano, Astrophysics, New York Institute of Technology, "Studies in Astrophysics"

Anne Wilson Goldizen, Biological Sciences, University of Tasmania, "Causes and Dynamics of Mate-Sharing in Tasmanian Native Hens"

Marie E. Machacek, Physics, Northeastern University, "Astrophysical Implications of Particle Unification"

Constance Royden, Cognitive and Neural Science, Wellesley College, "Human Heading Judgments in the Presence of Moving Objects"

Cheryl Anne Fillekes Stewart, Geophysics, Cornell University, "Thermal Convection in Earth and Venus"

Janet Talvacchia, Mathematics, Swarthmore College, "Non-minimal Critical Points for the Yang-Mills-Higgs Functional on TR3 with Arbitrary Coupling Constant"

Cheryl A. White, Neuroscience, Massachusetts Institute of Technology, "Role of Activity in Development of the Mammalian Visual System"

Scholars' Evaluations of the Bunting Year

The fellows unequivocally felt that their year at the Bunting was both successful and rewarding. The funding was cited as the single most important aspect of the program, as it provided support for both research and career development. Beyond the funding, there were several other program elements which the scholars cited as beneficial.

1. **Time to write and freedom to pursue research.** Consistently the scholars cited the importance and value of the time and freedom to get their work done. They were able to complete experiments; write articles, papers, and grants; and give several presentations in addition to their required colloquia. As biologist Anne Goldizen stated:

> During my year as a Science Scholar at Radcliffe College's Bunting Institute, I have had the time and freedom from teaching responsibilities to greatly advance my research on the dynamics and evolution of variable mating systems. In addition, I was offered and have accepted a tenure-track faculty position.

Physicist Marie E. Machacek explained how the year can benefit someone who already holds a tenured faculty post:

> The year as a Science Scholar has been a year of tremendous professional growth.... I was able to concentrate intensively on the astrophysics of structure formation, learn the field, experiment with several numerical techniques and computer systems, upgrade my skills in those critical areas, and apply all that I learned.

2. **Recognition from Bunting affiliation.** Several scholars mentioned the reputation of the Bunting Institute and their affiliation with the Harvard community as significant in gaining recognition for their work. Marie Machacek stated:

> Clearly my work this year at the Bunting and the recognition of the project by the Bunting and the National Science Foundation as worthy of funding has validated this research program within my home institution.

As she worked to expand her research to include studies of nervous system development in humans, Cheryl A. White realized the need to begin work on a medical degree:

> Undoubtedly, my participation in the Bunting Institute was helpful in my successful application to Harvard and other excellent [medical] schools. Indeed, during interviews, I was specifically asked about my association with the Bunting

Institute and the research I was carrying out under the ONR fellowship. Thus, the Bunting Institute Science Scholars program will have pl[illegible]d an important role in my development as a scientist and [illegible] contributor to the nation's health care system.

3. Opportunities for professional contacts. Since the fellowship requires a laboratory affiliation in the Boston area, scholars use the opportunity to develop new colleagues. These relationships often have continuing shared benefits. Nancy Butler, who affiliated with Harvard professor Joseph Montoya, commented:

> The interactions were mutually beneficial, as each of us shared our knowledge and experience in our respective fields. As a consequence of this in[illegible]ction, we have not only addressed the issues outlined [illegible] original proposal, but have also raised questions which we plan to address in a future collaborative effort.

Mathematician Janet Talvacchia stated that any potential difficulty in connecting with Harvard's Mathematics department was eased through her Bunting affiliation. She felt that these contacts greatly facilitated her research and will continue to do so in the future.

4. Interactions with other Bunting Fellows. Because the Bunting Institute is a multidisciplinary center for advanced studies, the fellows have the opportunity to work among scholars in fields very different from their own. Several Science Scholars found this to be an unexpected and invaluable source of support and intellectual stimulation. Constance Royden commended the excitement and commitment of other scholars for serving as a source of her re-inspiration and renewed energy.

Marie Machacek felt that the year had been "indescribable":

> Seldom can you find in academe a true community of scholars where respect, dialogue, and the free expression of ideas take precedence over moving up the academic ladder. The Institute creates such a community. I am deeply honored to have been a part of it and hope to continue to share the spirit of the Institute through mentoring of students and young women scholars in the years to come.

Program Highlights of the 1992-93 Year

1. Questionnaire mailed to all former Science Scholars. In preparation for a request to renew the Science Scholars grant in 1994, Bunting staff created a questionnaire that was mailed to all scientists who have participated in the Science Scholars program since 1981. The questionnaire focused on two issues: the scholars' experience while at the Institute, and the long- and short-term effects of the program.

The two-page questionnaire was mailed in August 1993 to the more than 75 women who have been Science Scholars. The questionnaire included both quantitative and qualitative questions. Quantitative questions included asking scholars to rate their level of satisfaction with several aspects of the Institute experience, such as contact with the laboratory and with the Harvard campus. Another question asked fellows to rate the effects over time from such aspects of the program as funding, professional contacts made during the year, and the opportunity to learn new techniques. The open-ended questions invited scholars to describe any career developments that could be attributed to the Bunting year.

Harvard/Radcliffe student Heidi B. Stayn worked with Assistant Director Linda Eisenmann on the development and administration of this questionnaire, which will be analyzed in the next year and discussed further in the 1994 technical report. It should provide useful summary information about the effects of this program.

2. Continuation of the Radcliffe Research Partners program. This program, begun in 1991 to provide undergraduate student assistants to Bunting fellows, continued to benefit the Science Scholars. These research partnerships are more than the ordinary work-study arrangement, which may not provide much substantive research work and may not include a mentoring component -- both of which are integral part of the Partnership arrangement. Several Science Scholars used this program, which continues to grow in numbers and in productivity. The Research Partnerships have the additional benefit of introducing young women science students to the issues involved in scientific research careers, while providing the sustained mentorship of senior women scientists.

3. Gender and Science Study Group. For several years, at the instigation of the fellows themselves, the Science Scholars have met regularly to examine issues related to the careers of women in science. In 1992-93, most of the scholars participated in this study group, which met every 2-3 weeks to share readings, experiences, and ideas. Two readings included The Outer Circle by Zuckerman, Cole, and Bruer, and Science magazine's second annual report on women in science.

Because several of the physical scientists shared interests, they developed another informal discussion group around mathematical and physics topics. These groups enhanced the experience of the science scholars, offering an additional opportunity to share resources.

Continuing Issues/Concerns

1. Technological support. One continuing concern for Science Scholars, as for other Bunting fellows, is the increasing demand for technological communication locally, nationally, and worldwide. The sophisticated technological research needs of the Science Scholars are usually met by the affiliated laboratories or departments. However, the Bunting Institute continues to face the need for advanced communications technology, such as reliable Internet access and ready availability of personal computers for fellows. Progress has been made this year by Radcliffe College, but many scholars continue to rely on the technological services of the affiliated departments.

2. Integration of Science Scholars with the Bunting community. One issue, which has eased over the past few years, is the difficulty for Science Scholars in dividing their time between their laboratories and the Bunting Institute. Progress has been made, however, in that all Science Scholars now present a colloquium within the regular Bunting Colloquium Series. Most often, the scientists choose to present a generalist talk to a lay audience at the Bunting, and most remark that they relish the challenge of making their material accessible. These talks, and the discussions they provoke among the Institute fellows, have been a public service which has also succeeded in enhancing the scientific literacy of the cohort of fellows. Science scholars are not deprived of the opportunity to present their work to a technical audience of peers, however; most choose to present a second talk in their department or another lecture series.

Future Plans of 1993 Scholars

Bonnie Berger will return to the Massachusetts Institute of Technology, where she will begin her term as Assistant Professor of Computer Science.

Nancy Butler accepted a tenure-track teaching post at the University of Montana, Flathead Station.

Rosanne DiStefano was awarded a second year of funding at the Bunting Institute, which will allow her to continue her retraining in astrophysics and expand her project in physics education.

Anne Wilson Goldizen accepted a tenure-track faculty position in the Department of Zoology at the University of Queensland in Australia. This will ensure the long-term continuation of her study of Tasmanian native hens and other species with unusually variable mating systems.

Marie E. Machacek returned to her tenured post in the Physics Department at Northeastern University. During the Bunting year, she created a multi-institution mentoring project for younger women physicists that she will take back to Northeastern.

Constance Royden was awarded a second year of funding at the Bunting Institute, which will allow her to continue to research with Professor Ellen Hildreth at Wellesley College.

Cheryl Anne Fillekes Stewart accepted a tenure-track teaching post in the Geology Department of New York University.

Janet Talvacchia returned to her teaching post at Swarthmore College, where she will stand for tenure in 1993-94.

Cheryl White is extending her research to human nervous system development. To do this, she will undertake medical studies at Harvard Medical School. She hopes to become involved in the health care of children with neurological disorders.

Selection for the 1994 Science Scholars Program

Applicant Pool

The Bunting Institute received a total of 27 eligible science applications, down from the 50 applications received the previous year. This smaller number suggests the need for continuing outreach work to support the progress made through the enhanced recruitment effort in the summer of 1991.

Of the 27 candidates, two were fellows from the 1992-93 Science Scholars program applying to extend their fellowship. A wide range of proposals in the physical and life sciences were represented in the applicant pool.

Selection Procedures

In the first stage, applications were reviewed by scientists who share the applicant's specialty. Based on this review, 21 of 27 applicants were advanced to the second stage, a success rate that far exceeds that of the regular Bunting fellowship program. As in past years, the science candidates continue to present very strong and competitive proposals. Three non-U.S. applicants were shifted to the general Bunting competition because of citizenship ineligibility.

The second-stage science committee reviewed the 21 candidates. That committee consists of senior scientists from institutions around the Boston area. The size differs each year depending on the variety of fields represented by applicants. In 1993 the committee consisted of the following eight scientists:

Howard Berg
Professor of Molecular Biology
Harvard University

Susan Carey
Professor of Experimental Psychology
Massachusetts Institute of Technology

Melissa Franklin
Professor of Physics
Harvard University

Irene Little-Marenin
Associate Professor of Astronomy
Wellesley College

Nanette Orme-Johnson
Professor of Biochemistry
Tufts University Medical School

Allan Robinson
Gordon McKay Professor of Geophysical Fluid Dynamics
Harvard University

Yum-Tong Siu
William Elwood Byerly Professor of Mathematics
Harvard University

John Wood
Professor of the Practice of Geology
Harvard University

Committee Decisions

The Science committee chose eight finalists and five alternates for Science Scholars funding. The proposals of the two fellows reapplying from the 1992-93 cohort were reviewed very favorably, and those two scientists (DiStefano and Royden) were recommended as finalists. The Bunting Institute was particularly pleased to have three of the new scholars in the field of mathematics.

The 1993-94 Science Scholars, their projects, and their affiliations include:

Rama Bansil (Physics)
Boston University
"Biophysical Studies of Mucin"

Susan Circone (Geology)
Harvard University
"Compressibility of Titanium-Bearing Silicate Liquids"

Rosanne DiStefano (Astrophysics)
New York Institute of Technology
"Studies in Theoretical Astrophysics"

Florence J. Lin (Applied Mathematics)
University of California at Berkeley
"Geometric, Numerical, and Nonlinear Dynamical Systems Studies in Molecular Dynamics"

Lauren L. Rose (Mathematics)
Wellesley College
"Algebraic Combinatorics and Multivariate Splines"

Constance Royden (Computational Neuroscience)
Wellesley College
"Human Heading Perception: Computational and Psychophysical Studies"

Leila Cynthia Schneps (Mathematics)
Centre National de la Recherche Scientifique, France
"The Absolute Galois Group from a Geometric Viewpoint"

Lisa Vawter (Molecular Evolution)
Harvard University
"Evolutionary Genetics of Termites"

Summary

The 1992-93 cohort of Science Scholars experienced a satisfying and successful year at the Bunting Institute, as both their job-hunting success and their summary reports confirm. Three of the fellows won tenure-track university positions, one was accepted to medical school to extend her research studies, and two junior faculty returned to their institutions with strengthened research records. All made significant progress on their research, as is evidenced by their attached reports and papers.

The 1993-94 cohort promises to be a strong group for the Institute. Three of the scholars are mathematicians, who will be joined by a fourth mathematician in the general Bunting fellowship program. The new cohort is well-balanced among disciplines, with several of the fellows practicing in the physical sciences.

APPENDICES

I. Roster of 1992-93 Bunting Institute Fellows

II. Roster of 1993-94 Bunting Institute Fellows

III. Reports of 1992-93 Science Scholars

IV. Papers and Abstracts of 1992-93 Science Scholars
(only provided in one copy of this Technical Report)

I. ROSTER OF 1992-93 BUNTING INSTITUTE FELLOWS

The Mary Ingraham Bunting Institute of Radcliffe College

1992-93 Fellows

DELIA D. AGUILAR
Fellow (Women's Studies)
Bowling Green State University
The Women's Movement in the Philippines

EDITH J. BARRETT
Hermon Dunlap Smith Fellow (Political Science/Public Policy)
Brown University
Social Welfare and the Political Socialization of Inner-City Youths

DEBORAH BELLE
Evelyn Green Davis Fellow (Psychology)
Boston University
Children's After-School Experiences: A Contextual Analysis

BONNIE BERGER
Science Scholar (Computer Science)
Massachusetts Institute of Technology
Efficient Parallel Algorithms

NANCY M. BUTLER
Science Scholar (Aquatic Ecology)
Great Lakes Environmental Research Laboratory
Nitrogen Isotope Fractionation in Marine Zooplankton: Effects of Trophic Status, Food Quality, and Development Stage

WHITNEY CHADWICK
Fellow (Art History)
San Francisco State University
The Inn of the Dawn Horse: The Paintings and Writings of Leonora Carrington

KIANA DAVENPORT
Bunting Fellow (Creative Writing)
Independent Writer
Pacific Woman, Short Story Collection

MALENA DE MONTIS
Peace Fellow (Peace Studies)
Center for Democratic Participation and Development, Managua, Nicaragua
Building Peace and Democracy in Nicaragua: The Role of Women's Groups and Non-Governmental Organizations

ROSANNE DiSTEFANO
Science Scholar (Astrophysics)
New York Institute of Technology
Studies in Astrophysics

MARGUERITE FEITLOWITZ
Bunting Fellow (Creative Writing)
Independent Writer
A Lexicon of Terror: Argentina and the Legacies of Torture

ANN FERGUSON
Fellow (Philosophy)
University of Massachusetts, Amherst
A Study in Feminist Ethics: Why Should I? Feminism and Moral Revolution

ANNE WILSON GOLDIZEN
Science Scholar (Biological Sciences)
University of Tasmania
Causes and Dynamics of Mate-Sharing in Tasmanian Native Hens

MARCIE HERSHMAN
Fellow (Creative Writing)
Tufts University
Safe in America, a novel

JEANNE MARIE JORDAN
Fellow (Film)
Independent Filmmaker and Producer
Last Stand at Troublesome Creek: A Midwestern

ROSEMARY A. JOYCE
Fellow (Anthropology)
Harvard University
Gender and Power in Prehispanic Mesoamerica

MARIE E. MACHACEK
Science Scholar (Physics)
Northeastern University
Astrophysical Implications of Particle Unification

DENISE MARIKA
Evelyn Green Davis Fellow (Visual Arts)
Independent Artist
Video Sculptures and Projections

LINDA McCARRISTON
Bunting Fellow (Poetry)
Independent Poet
"Route 2, East/West" and "Forward Desire"

SUSAN LYNN MEYER
Fellow (Literature)
Wellesley College
Gender and Empire: Figurative Structures in the Fiction of Charlotte Brontë, Emily Brontë, and George Eliot

JANE MIDGLEY
Fellow (Peace Studies)
Women's International League for Peace and Freedom
Creating a Peace Economy : De-Militarization and the Transformation of Federal Resource Distribution in the U.S.

JUDITH NIES
Fellow (Creative Writing)
Independent Writer
Roberta Blackgoat and the Moccasin Telegraph: Indigenous Peoples and Global Corporations

LETITIA EVA OBENG
Distinguished International Visitor at Radcliffe College (Parasitology)
Environmental Management Services in Ghana
Parasites, People and their Wastes

LEILA PHILIP
Fellow (Creative Writing)
Independent Writer
Throwing Off the Mask: Narratives on Japanese Women

MARILENE PHIPPS
Fellow (Visual Arts)
Independent Artist
Visions of Light: The Haitian Landscape

CHRISTINA ROBB
Fellow (Journalism)
The Boston Globe
Changing the Voice of Psychology

ELLEN ROTHENBERG
Bunting Fellow (Visual Arts)
Independent Artist
A Probability Bordering on Certainty

CONSTANCE ROYDEN
Science Scholar (Cognitive and Neural Science)
Wellesley College
Human Heading Judgments in the Presence of Moving Objects

OFELIA SCHUTTE
Fellow (Philosophy)
University of Florida
Gender, Community, Utopia: Essays in Feminist Ethics

ROSALIND H. SHAW
Fellow (Anthropology)
Tufts University
Women, Men and Divination: Temne Negotiations of Gender and Self

SHANTI MARIE SINGHAM
Fellow (European History)
Williams College
Public Opinion, Police Records, and the Origins of the French Revolution: The Importance of the Maupeou Years, 1770-1775

DEBRA SPARK
Fellow (Creative Writing)
Tufts University and Emerson College
Dog Star/Coquil

SARAH SPENCE
Fellow (Comparative Literature)
University of Georgia
Female Voices in Vergil's Aeneid

CHERYL ANNE FILLEKES STEWART
Science Scholar (Geophysics)
Cornell University
Thermal Convection in Earth and Venus

LINDA K. STOUT
Fellow (Public Policy)
Piedmont Peace Project
Building a Multi-Class, Multi-Racial Movement for Social Change

JANET TALVACCHIA
Science Scholar (Mathematics)
Swarthmore College
Non-minimal Critical Points for the Yang-Mills-Higgs Functional on TR3 with Aribitrary Coupling Constant

FREDRIKA J. TEUTE
Berkshire Summer Fellow (American History)
Institute of Early American History and Culture
"The Duties of Our Sphere": Home as Constraint and Liberation in the Early Republic ; The Writings of Margaret Bayard Smith

ANN F. THOMAS
Fellow (Law)
Fried, Frank, Harris, Shriver & Jacobson Law Firm
The Impact of the Internal Revenue Code on Women

MARY E. VOGEL
Fellow (Sociology)
State University of New York, Stony Brook
The Social Origins of Plea Bargaining: Law and the Courts in the Process of State Formation, 1830-1890

KATHLEEN WEILER
Fellow (Education)
Tufts University
Women Teachers in Country Schools: California, 1850-1950

CHERYL A. WHITE
Science Scholar (Neuroscience)
Massachusetts Institute of Technology
Role of Activity in Development of the Visual System

NORMA J. WIKLER
Evelyn Green Davis Fellow (Sociology)
University of California, Santa Cruz
Water On Stone: An Interpretive Account of the Movement to Eliminate Gender Bias in the Courts

ZIPPORAH BATSHAW WISEMAN
Fellow (Law)
University of Texas School of Law
Biography of Soia Mentschikoff

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II. ROSTER OF 1993-94 BUNTING INSTITUTE FELLOWS

The Mary Ingraham Bunting Institute of Radcliffe College
1993–94 Fellows

PAULA L. AYMER
Fellow (Sociology)
Tufts University
Capitalist Incursions and Intra-Caribbean Migration: A Case Study of Eastern Caribbean Migrant Domestics in Aruba

RAMA BANSIL
Science Scholar (Physics)
Boston University
Biophysical Studies of Mucin

ELLA L.J. EDMONDSON BELL
Massachusetts Institute of Technology
STELLA M. NKOMO
University of North Carolina at Charlotte
Radcliffe Visitors-In-Residence
(Management and Organizational Behavior)
Life Journeys of Women in Corporations

KAROL BENNETT
Evelyn Green Davis Fellow (Vocal Performance)
The Rivers School of Music
Vital Vocal Vistas

SARAH MAUSOLFF BUEL
Evelyn Green Davis Fellow (Law)
Suffolk County District Attorney's Office
Family Violence: The Crisis and Innovative Responses

ELIZABETH BUSSIERE
Fellow (Political Science)
University of Massachusetts at Boston
The American Jury and the Decline of Popular Justice

MARIA MAGDALENA CAMPOS-PONS
Bunting Fellow (Visual Arts)
Independent Artist
History of People Who Were Not Heroes: Growing Up in a Slave Barrack

HELEN HARDEN CHENUT
Fellow (History)
Mount Holyoke College
Gender, Politics, and Culture in a French Textile Town, Troyes, 1880–1939

SUSAN CIRCONE
Science Scholar (Geology)
Harvard University
Compressibility of Titanium-Bearing Silicate Liquids

M.E. KROPP DAKUBU
Fellow (Linguistics)
University of Ghana
Crossing the Bar: Language, History, and Ethnicity in a West African City

E. VIRGINIA DEMOS
Marian Cabot Putnam Fellow (Psychology)
Harvard Medical School and Beth Israel Hospital
The Psychic Life of the Infant

DENISE DILNOT
Fellow (Visual Arts)
Independent Artist
The Underside of Things

ROSANNE DI STEFANO
Science Scholar (Astrophysics)
New York Institute of Technology
Studies in Theoretical Astrophysics

ROBIN FLEMING
Bunting Fellow (Medieval History)
Boston College
Law and Society in Eleventh-Century England

ROSE E. FRISCH
Fellow (Reproductive Biology)
Harvard School of Public Health
Energy Resources, Puberty, and Fertility

BETH ANN GOLDRING
Hermon Dunlap Smith Fellow (Peace Studies)
Palestinian Federation of Women's Action Committees
Developing Context-Specific Human Rights Work

BARBARA HILDT
Radcliffe Fellow in Public Policy (Public Policy)
The Medical Foundation, Boston
The New Politics of Inclusion: Transforming Power, Creating Change

ROBIN KILSON
Bunting Fellow (Black Women's Studies)
Massachusetts Institute of Technology
Passing for Ariel: The History of Black Women Doctorates in American Academia, 1921–1991

MODUPE LABODE
Berkshire Summer Fellow (History)
Iowa State University
U.S. Women's Missionary Societies and Africa, 1880–1920: An Exploration of Race, Gender, and Nationality

MARY LASSEN
Bunting Fellow (Social Policy)
Committee for Boston Public Housing
Empowering Approaches to Service Delivery and Leadership Development in Public Housing Communities

FLORENCE J. LIN
Science Scholar (Applied Mathematics)
University of California at Berkeley
Geometric, Numerical, and Nonlinear Dynamical Systems Studies in Molecular Dynamics

PATRICIA CLEARY MILLER
Radcliffe Alumna Fellow (Poetry)
Rockhurst College
Without Ice Axes

DEBRA C. MINKOFF
Fellow (Sociology)
Yale University
Associating for a Change: The Shaping of American Social Action

VIRGINIA NEWES
Fellow (Musicology)
Eastman School of Music
Questions of Genre in the French Secular Song, ca. 1350–1420

HANNA PAPANEK
Fellow (Nonfiction)
Boston University
In Search of Exile

ANN PATCHETT
Bunting Fellow (Fiction and Nonfiction)
Independent Writer
Taft

SUSAN POWER
Bunting Fellow (Fiction)
University of Iowa
The Grass Dancer, a novel

LAUREN L. ROSE
Science Scholar (Mathematics)
Wellesley College
Algebraic Combinatorics and Multivariate Splines

CONSTANCE ROYDEN
Science Scholar (Computational Neuroscience)
Wellesley College
Human Heading Perception: Computational and Psychophysical Studies

LEILA CYNTHIA SCHNEPS
Science Scholar (Mathematics)
Centre National de la Recherche Scientifique, France
The Absolute Galois Group from a Geometric Viewpoint

LESLIE C. SHAW
Fellow (Anthropology and Archaeology)
University of Massachusetts at Boston
The Emergence of Inequality in the Maya Lowlands

PATRICIA L. SIPE
Fellow (Mathematics)
Smith College
DES and Risk: Subjectivity in Statistical Methods for Public Health

SANDRA STEINGRABER
Evelyn Green Davis Fellow (Poetry and Biology)
Columbia College, Chicago
Post-Diagnosis: Ecological Poetry

RITSUKO TAHO
Bunting Fellow (Visual Arts)
Massachusetts Institute of Technology
Transformation: Language of Nature

SUSAN L. TANANBAUM
Fellow (British and Jewish History)
Bowdoin College
Making "Worthy Citizens": The Anglicization of Immigrant Women and Children in the Jewish East End, 1880–1939

JUDITH THOMPSON
Peace Fellow (Peace Studies)
Children of War, Inc.
Rising From the Ashes: Building a Community of Hope

AMY C. TISHELMAN
Children's Hospital–Radcliffe College Joint Fellow in Family Violence (Clinical Psychology)
Children's Hospital and Harvard Medical School
Systems Analysis in Family Violence: Exploring the Fundamental Conflicts

JESSICA TREADWAY
Fellow (Fiction)
Independent Writer
Shirley Wants Her Nickel Back, a novel

LISA VAWTER
Science Scholar (Molecular Evolution)
Harvard University
Evolutionary Genetics of Termites

MAXINE YALOVITZ-BLANKENSHIP
Fellow (Visual Arts)
Independent Artist
Painting an Epic Poem

ABBY ZANGER
Fellow (French Literature)
Harvard University
Exploding Symbols: Imagining the Queen in the Marriage of Louis XIV

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III. REPORTS OF 1992-93 SCIENCE SCHOLARS

YEAR-END REPORT

Submitted To
The Office of Naval Research
12 July 1993

By

Nancy M. Butler, Bunting Science Scholar
University of Montana
Flathead Lake Biological Station
311 Bio Station Lane
Polson MT 59860

The time I spent as a Science Scholar, while only six months in duration, proved to be extremely rewarding both from a professional as well as personal perspective. The interactions between Dr. Joseph Montoya and myself at Harvard University were mutually beneficial, as each of us shared our knowledge and experience in our respective fields. As a consequence of this interaction, we have not only addressed the issues outlined in the original proposal, but have also raised questions which we plan to address in a future collaborative effort. In additional to professional rewards, there were also personal rewards realized during my tenure at the Bunting Institute. Probably the most obvious benefit was the opportunity to interact with women who are professionals in fields far removed from my own. I think it is easy to trivialize the achievements of those in other professions when struggling to succeed in one's own field. However, when you have the opportunity to look more closely, to know the person behind the work, you can recognize and share the frustration, desire, and talent that drive each of us. And, during my tenure as a Bunting Fellow, I also had the opportunity to make some close friends. That is a benefit of immeasurable worth.

SUMMARY OF THE YEAR'S WORK

My initial work concentrated on investigating the population and feeding dynamics of the research organisms. These studies are listed below.

1. Finished experiments on the reproductive dynamics of the rotifer *Brachionus plicatilis*.

2. Finished experiments on the salinity tolerance of the rotifer *Brachionus plicatilis* and

3. Measured the functional response of the copepod *Acartia tonsa* feeding on the rotifer *B. plicatilis*.

4. Measured the functional response of the copepod *Acartia tonsa* feeding on the alga *Chroomonas salina*.

5. The effect of diet on the egg production rate of the copepod *Acartia tonsa*.

Once I had an understanding of the biology and physiology of the study organisms, I conducted the following experiments, which were designed to investigate the effects of diet and development state on the stable carbon and nitrogen isotope signatures of the copepod *Acartia tonsa* .

1. The isotopic signatures of *Acartia tonsa* maintained on an omnivorous diet (the rotifer *Brachionus plicatilis* and the alga *Chroomonas salina*).

2. The isotopic signatures of *Acartia tonsa* maintained on a carnivorous diet (rotifers only).

3. The isotopic signatures of *Acartia tonsa* maintained on an herbivorous diet (algae only).

4. The rate of change in isotopic signature of *Acartia tonsa* switched from an herbivorous diet to an omnivorous diet.

5. The rate of change in isotopic signature of *Acartia tonsa* switched from an omnivorous diet to a carnivorous diet.

6. The isotopic signature of the naupliar and copepodite stages of offspring produced by *Acartia tonsa* maintained on either herbivorous, omnivorous, or carnivorous diets.

While the above experiments have been conducted, the data remain to be analyzed. The mass spectrometer, which measures the isotopic signature of the samples, was out of commission during my stay at Harvard. These samples are currently being analyzed and I should have the data by the end of this summer.

PRESENTATIONS MADE

17 February 1993: Nitrogen Isotopes in Planktonic Food Webs. The Bunting Institute Colloquium Series

1992-93 Bunting Science Scholar Report

Rosanne Di Stefano

Completed Work

During the first year of my Bunting Science Scholarship I have worked on several research projects. Below I will briefly describe the work that has been completed. To complement these brief descriptions, and to provide references to the relevant literature, three completed papers are attached. One of these will be published in a conference proceedings. The other two have been submitted to the *Astrophysical Journal* for publication. In addition to this work in the area of theoretical astrophysics, I have participated in a project on physics-education research. This led to an article in *Physics Today*.

1. Formation and Evolution of Cataclysmic Variables in Globular Clusters

This paper represents the project that occupied the largest chunk of my time during the year. It is a study of the formation (through two-body tidal capture) and evolution of cataclysmic variables in globular clusters. Through considering the CVs throughout the epoch of mass transfer, we realized that the lifetime of this phase, and hence of the CVs themselves, can be very long. This led us to an estimate of the number of active systems that is significantly larger than previous estimates. Because we followed each active system in detail, we were also able to predict the distributions of accretion luminosity and of orbital period of systems that are active in the present epoch. These predictions can provide a guide to observers, in that they clearly indicate what theory predicts about CVs in globular clusters. For the same reason, they can be verified or disproved by observation. Should the letter happen, then the mechanism of two-body tidal capture would be seriously constrained.

In fact, very few CVs have been discovered in globular clusters. However, the advent of the Hubble Space Telescope, of Rosat, and now ASCA, has provided us

with sensitive new tools to proceed with the search. There is some suggestive evidence of low-luminosity X-ray sources (discovered with Rosat) in globular clusters. It is likely that the state of our knowledge about the presence of CVs will improve considerably during the coming decade.

Cataclysmic Variables in Globular Clusters

Predictions of a Population of CVs in Globular Clusters

(with S. Rappaport), Submitted to *The Astrophysical Journal* on 17 July 1993.

Formation and Evolution of Cataclysmic Variables in Globular Clusters

(with S. Rappaport), to appear in *Proceedings of the 2nd Technion Haifa Conference on Cataclysmic Variables and Related Objects*, Eilat, Israel, January 1993,
eds. O. Regev and G. Shaviv

2. Supersoft X-Ray Sources

One explanation that has been put forward for these highly luminous, but very soft X-ray sources, is steady nuclear burning of matter that has accreted onto a white dwarf from an extended companion. The question of whether such a scenario can explain the numbers of systems that have already been discovered and the larger population that can be inferred from the observed systems, hinges on whether a large enough fraction of primordial binaries can evolve into systems in which a main-sequence or subgiant star transfers mass to a white dwarf companion on a time scale that is governed by its own thermal time scale. Saul Rappaport, J.D. Smith (an MIT undergraduate), and I addressed this question. Our approach involved a Monte Carlo analysis and analytic work. We studied seven models, which included different assumptions about the mass ratio distribution and period distribution of zero-age binaries, as well as different assumptions about the physics of the evolving binaries. For example, since the efficiency with which a close binary system can

eject a common envelope is not well known, we studied variations in the efficiency factor. We also studied the possible effect of magnetic braking after the common envelope phase and before the final epoch of mass transfer.

Most of the scenarios predict a fairly large number of supersoft sources: $\sim$ 1000, 2800, 120, and 15 in the Galaxy, M31, the LMC, and the SMC, respectively. However, a distribution of mass ratios that favors low mass secondaries ($< 0.8 M_{\odot}$) might reduce these numbers by an order of magnitude. There are also uncertainties related to our present understanding of the conditions that are necessary in order for matter which is accreted by a white dwarf to be able to burn steadily. Further work which addresses these questions, and also questions related to the observability of supersoft X-ray sources is under way.

Luminous Supersoft X-Ray Sources

Formation and Evolution of Luminous Supersoft X-Ray Sources
(S. Rappaport, R. Di Stefano, J.D. Smith), Submitted to *The Astrophysical Journal* on 3 August 1993.

Work in Progress

We are engaged in studies that extend each of the completed projects.

1. **Close Binary Systems in Globular Clusters**

The work on tidal capture systems in globular clusters is being extended by the inclusion of three-body processes. There are also some conceptual issues that have been raised by this work, including the role played by mass stripping during capture and circularization, and the conditions under which mass transfer from one star to a close companion can be be a stable (as opposed to a runaway) process. I am interested in pursuing these issues in the near future.

2. **Observability of Supersoft X-Ray Sources**

The work on supersoft sources is now being studied from another perspective—the perspective of observability. I have begun to work with the so-called PIMMS software to explore the issue of how many of the systems that we think may be

present in M31, the LMC, the SMC, as well as in our own Galaxy, should have been observed in the Rosat all-sky survey. The answers can provide an important check for the model of unstable mass accretion onto the surface of a white dwarf.

There are two other projects which I have worked on during the year that I also hope to complete during the next year. I will actually be making a presentation on the work discussed in *item 3*, below, at a meeting on neutron stars in mid-October.

3. Search for Chaos in Astrophysical Data Sets

This is a project which has occupied a good deal of my time during the past year. Although chaotic behavior is expected to occur in many astrophysical systems, the challenge of finding convincing evidence of such behavior in real data sets, especially X-ray data, is one that remains largely unmet. This year I worked with MIT senior Marc Bockrath on analysis of data from the Rapid Burster. Marc wrote his senior thesis on this project, which consisted of applications of standard tests of dimensionality as well as dynamics-based analyses, like the computation of Lyapunov exponents. This work was inconclusive. I am continuing to study the data with forecasting techniques, which I have been working on with another student, Rick Jenet.

4. Approximate Integrals of the Motion for Galactic Potentials

This is work that is being dome in collaboration with MIT Professor Paul Schechter and with MIT undergraduate Ann Esin. We are using a combination of analytic and numerical techniques to construct approximate integrals of the motion. This project is less well-developed than the others that I have been working on, because we have not yet been able to spend as much time on it.

Public Presentations

During the year I gave a seminar on my work in globular cluster to the theory group at Fermilab, a short talk at the June meeting of the *American Astronomical Society*, the Bunting Colloquium, and an invited lecture on physics education at the April meeting of the *American Physical Society*.

Submission of Grant Proposals

During the year of my Bunting Science Scholarship I submitted three proposals. One was for the VPW program, and this was not funded. The other two are purely for research funding, and are still pending. One is an NSF proposal for work on close binary systems, and was submitted with Saul Rappaport. The second was a proposal to use ASCA to make observations of 47 Tuc. My collaborators on this project would be Chris Becker and Saul Rappaport. The goal of these observations would be to do a spectral study that could help to determine the nature of the X-ray sources near the center of the cluster. The motivation for this study stems, at least in part, from the theoretical work that we have done on CVs in globular clusters.

Anne Wilson Goldizen
Bunting Institute Science Scholar - 1992-93

Year-end Report for the Office of Naval Research
2 August 1993

During my year as a Science Scholar at Radcliffe College's Bunting Institute, I have had the time and freedom from teaching responsibilities to greatly advance my research on the dynamics and evolution of variable mating systems. In addition, I was offered and have accepted a tenure-track faculty position in the Department of Zoology at the University of Queensland in Australia. I will take up this position in September of this year. This position will ensure the long-term continuation of my study of Tasmanian native hens and other species with unusually variable mating systems.

During this year, I supervised a fourth season of field research on the variable mating systems of Tasmanian native hens (Tribonyx mortierii: Rallidae) on Maria Island, off the east coast of Tasmania, Australia. From September through December I had field assistants carrying out field work at Maria Island and then I spent the months of January and February doing field work myself. This personal involvement in the field work would not have been possible had I had a teaching position. I wrote two articles on the data that I collected on the native hens from 1989 through 1992 - one is in press in the journal Animal Behaviour and the other will be submitted within weeks to Behavioural Ecology and Sociobiology. I have also analyzed data on many other aspects of the study; I will write these data up for publication during the next several months. I also wrote three major grant applications to ensure the long-term continuation of this field project. I applied to the National Geographic Society for funds for my September 1993 - February 1994 field season and was granted $15,550. In addition, I applied to the Australian Research Council for two three-year research grants - one to continue field work from 1994 through 1996 and one to fund genetic work on the native hen population. I will not know the result of these applications to the ARC until November of this year.

I also wrote a major article this year on variable mating systems in saddle-back tamarins (Saguinus fuscicollis: Callitrichidae: Primates), based on a thirteen-year field study of this species, for a symposium volume to be published in American Journal of Primatology. This volume is a collection of articles on long-term field studies of tamarins and marmosets. From 1979 through 1986 I carried out a study of individually marked wild saddle-back tamarins in Peru's Manu National Park. This study has been continued through the present by two subsequent graduate students, making it the longest field study of any callitrichid species. My two research projects, on variable mating systems in Tasmanian native hens and saddle-back tamarins, are closely interlinked, such that results from each study help the other study.

Publications and manuscripts - 1992-93

Goldizen, A. W., A. R. Goldizen and T. Devlin. 1993. Unstable social structure associated with a population crash in the Tasmanian native hen (Tribonyx mortierii). Animal Behaviour.

Gibbs H. L., A. W. Goldizen, C. Bullough and A. R. Goldizen. In preparation. Parentage analyses of multi-male social groups of Tasmanian native hens: Genetic evidence for monogamy and polyandry. To be submitted to Behavioural Ecology and Sociobiology.

Goldizen, A. W., J. Mendelson, M. van Vlaardingen and J. Terborgh. In press. Saddle-back tamarin (Saguinus fuscicollis) reproductive strategies: evidence from a thirteen-year study of a marked population. American Journal of Primatology.

Talks and presentations - 1992-93

November 12, 1992 - "Field research on Tasmanian native hens" - talk presented to the keepers at the Roger Williams Park Zoo, Providence, RI

January 20, 1993 - "Mate-sharing in Tasmanian native hens and saddle-back tamarins" - seminar presented to the Department of Biological Sciences, Flinders University, Adelaide, Australia

January 28, 1993 - " Mate-sharing in Tasmanian native hens and saddle-back tamarins" - seminar presented to the Department of Zoology, University of Queensland, Brisbane, Australia

March 31, 1993 - "Evolution of cooperative polyandry in saddle-back tamarins and Tasmanian native hens" - seminar presented to the Department of Biology, Villanova University, Villanova, PA

April 21, 1993 - "Males sharing mates: an evolutionary paradox" - colloquium presented at the Bunting Institute, Radcliffe College

Mary Ingrahamson Bunting Science Scholars Final Report
Marie E. Machacek

During the past year as a Science Scholar I studied the growth of structure in a universe dominated by self-interacting dark matter (SIDM). The general properties of this new class of dark matter were determined in a paper completed the year prior to the fellowship that appeared in the Astrophysical Journal in October 1992 [Paper 1]. The initial part of the fellowship was spent studying the newly published results from the Cosmic Background Explorer satelite (COBE) on measured large angle temperature anisotropies in the universe. This measurement provided an absolute normalization for existing cold dark matter models of structure formation and gave me insight into the appropriate background literature for the problem I was studying. Through the Bunting I was also able to make contact with Prof. Edward Bertschinger of MIT, who is an area expert in structure formation calculations, and was guided by him to the seminal literature in the field.

After this initial period of background study, I determined that the most appropriate formalism to study structure formation in this system was the gauge invariant formalism of Bardeen as applied by Abbott & Wise to perfect fluids coupled only through gravity. The coupled differential equations for a two component universe consisting of self-interacting dark matter and radiation were derived for the three epochs of interest determined by the changing behavior of the dark matter as the universe cools. The equations for the relativistic epoch were solved analytically. The solution to the equations that track the evolution of adiabatic scale invariant density perturbations through the self-interacting epoch and the SIDM decoupled epochs could not be obtained analytically. A major advantage of pursuing this work at the Lyman Laboratory of Physics through the Bunting Institute was the ready availability of adequate computer facilities and the opportunity to learn and experiment with several programming languages and software packages. I found that the software package Mathematica was particularly useful due to the ease of programming coupled ordinary differential equations and of implementing the necessary boundary conditions at each epoch boundary. It was also particularly useful in a first survey study of the behavior of self-interacting dark matter due to the excellent interactive graphics so that solutions could be tracked visually while the model parameter choices and numerical procedures were being refined.

The differential equations for the growth of adiabatic perturbations were solved numerically for two representative choices of SIDM model parameters and for both extremes of the Hubble parameter that describes the present expansion rate of the universe. The spectra so obtained were normalized to the COBE temperature anisotropy data and then used to study the galaxy-galaxy correlations, to calculate the excess power function (a normalization independent measure of the shape of the spectrum required by galaxy count

data), to determine the root mean square peculiar velocity distribution as a function of averaging scale, to calculate the cosmic mach number, and to investigate the mass dispersion as a function of mass that gives insight into the redshifts at which gravitational instabilities cause the perturbations to grow nonlinearly and collapse into the structures we see today.

The results of this study, presented in Paper 3, indicate that self-interacting dark matter models suppress power at small scales compared to cold dark matter models. During the epoch in which their particle number changing self-interactions are important, their temperature remains high so that a nonnegligible adiabatic sound velocity inhibits the early formation of small scale structure. I found that models in which the adiabatic sound velocity is 2 to 7% of its relativistic value at the time of recombination appear to fit the available observational data well.

In addition to the completed work described above, the project has suggested several projects for continued study. The expected anisotropies in the cosmic microwave background as a function of angular scale need to be determined. The model admits the particularly interested possibility that a small scale entropy perturbation in the self-interacting dark matter might arise due to a phase change at the boundary between the relativistic and self-interacting epoch and contribute to galaxy formation. Recent work by E. Carlson on cosmological models that produce a small cosmological constant might also naturally produce self-interacting dark matter. These models might resolve the apparent discrepancy between age determinations for a flat universe and ages inferred for globular clusters. The observational predictions of such models for structure formation and for temperature anisotropies in the microwave background need to be explored. Thus the Bunting fellowship has been instrumental in allowing me to define an ongoing research program in this field.

Talks presented during my fellowship year are the following:

1. "Self-interacting Dark Matter: An Alternative Scenario?" contributed paper selected for presentation at the 16th Texas Conference of Relativistic Astrophysics/ 3rd Conference on Particles, Strings and Cosmology, Berkeley, CA , December 1992.
2. "In Search of the Origins of Structure", Colloquium presented as part of the Mary Ingrahamson Bunting Institute Colloquium Series, May 1993.
3. "Growth of Adiabatic Density Perturbations in Self-interacting Dark Matter", technical seminar, Dept. of Physics, Harvard University, June 1993.

Papers written or published during my fellowship year are the following:

1. E. D. Carlson, M. E. Machacek, & L. J. Hall , 1992 , "Self-interacting Dark Matter", Astrophysical Journal, 398, 43.
2. M. E. Machacek, E. D. Carlson, & L. J. Hall, 1993, "Self-interacting Dark Matter: An Alternative Scenario?" in Texas/PASCOS 92 Relativistic

Astrophysics and Particle Cosmology, ed. C. W. Akerlof & M. A. Srednicki (Annals of the New York Academy of Sciences, Vol. 688), 681.

3. M. E. Machacek, "Growth of Adiabatic Perturbations in Self-Interacting Dark Matter", preprint no. NUB 3070, HUTP-93/0024, submitted to Astrophysical Journal, August 9, 1993.

Finally the Bunting Institute has allowed me to become more actively involved in mentoring activities to encourage young women to pursue careers in mathematics and science. I was privileged to be able to participate as a Big Sister mentor to a high school student interested in chemistry and physics attending the Radcliffe Summer Program in Science and hope to maintain an ongoing relationship with the Radcliffe Science Alliance. Also I joined with Prof. Elizabeth Simmons of Boston University and Prof. Melissa Franklin of Harvard University (both women at Harvard during my fellowship year) to prepare a preliminary proposal to the National Science Foundation for funding to establish the Boston Women's Science Symposia, a series of cross institutional, participatory symposia and mentoring activities to encourage young women interested in science to become involved in research and in the presentation of their research to the professional community early in their careers.

Year-End Report **Constance S. Royden**

Bunting Institute Science Scholars Program

This year, I received only six months of funding from the Bunting Institute Science Scholars program, beginning in March, 1993. During these past few months, I have concentrated on two research goals. First, I have been finishing some computational work on models developed to explain my previous data on human heading judgments. Second, I have been designing and building a system to perform psychophysical experiments to determine how well humans judge heading in the presence of moving objects. I have also run some preliminary experiments on this project.

Computational Modeling:

During my work with Dr. Martin Banks at UC Berkeley, I conducted a set of experiments to determine how well humans judge their direction of motion when they are both translating and rotating. This type of motion occurs for a person moving along a straight line while making eye or head movements. We discovered that for moderate speeds of rotation, 2.5 and 5.0 degrees per second, people rely on information about eye movements to judge heading. When viewing a simulated translation over a textured ground plane while tracking a moving target on the screen, people can judge their heading quite accurately at tracking speeds up to 5 degrees per second. However, when people fixate a stationary target while the translation and rotation is simulated in the moving display, they no longer accurately report their heading even though the retinal image is identical to that of the previous condition (Royden et. al., 1992). In fact, the perception of the movement differs between the condition when observers move their eyes and the condition in which the eyes remain stationary. In the first case, observers report that they appear to be moving in a straight line while making an eye movement. In the second case, observers report that they are moving on a curved path. These results raise two questions that potential models of heading perception must address. First, how do observers incorporate the eye movement information into their heading calculation in the condition where observers move their eyes? Second, how does the brain calculate the curved path in the case where observers eyes are fixed, and what position on this path corresponds to their reported heading?

I have been examining the second of these two questions. I have shown that the motion of points on the viewing screen in the case of simulated rotation is very similar to the motion that would occur if the observer were actually moving on a curved path, rather than moving in a straight path while rotating the eyes. Under the conditions we used, I have calculated that the largest difference in the two paths is 1.3 degrees. This occurs for points on the ground plane that are closest to the observer and in the furthest periphery of the display. The trajectories of points on the horizon of the ground plane and at the periphery of the screen differ by only 0.2 degrees. Therefore it may be quite difficult to distinguish between these two simulated motions. I hypothesize that when the eyes are not moving, the visual system automatically chooses the curved path motion. It can rule out motion on a straight line while moving the eyes, because the oculomotor system provides the information that the eyes are not moving.

Motion on a curved path does not give a strong reference for a unique heading direction, and yet observers very consistently reported one particular heading for these trials. I have been modeling two possible mechanisms the visual system might use to choose a heading in these cases. The first mechanism extends the mechanism thought to operate when the observer undergoes no rotations. In this case of pure translation, the image of each point moves directly away from a point on the image surface that corresponds to the observer's heading. One can easily find this point by finding the intersection of lines

through the velocity vectors for each point in the scene. Perrone (1992) has shown how cells in visual cortex might accomplish this computation. Perhaps, when forced to judge overall heading with rotations, the visual system uses the same mechanism, i.e. it finds the best intersection of lines through the velocity vectors for each point in the image. To examine this possibility, I have constructed a computer program to find the best intersection point of lines through the velocity vectors in the scenes used in our experiments. The program uses a Least Squared Error (LSE) algorithm to calculate this point. I have found that these estimates fit the data remarkably well for the experiments that simulated a ground plane, but not for experiments simulating approach to a three-dimensional cloud of points or two transparent planes. In these cases, there are significant differences between the estimates and the data. I have concluded based on this analysis that this mechanism is not sufficient to explain our results.

Another possibility is that the visual system uses some point on the perceived curved path to generate an overall heading estimate. For example, people might be estimating a heading consistent with the direction of a line tangent to the curve at some point, or they might judge their heading to be along a line from their eye position through some point on the curve. I have done calculations to determine which point on this path yields heading estimates consistent with the data. This analysis shows that finding the direction of a line from the observer's eye position through the closest visible point on the circular path yields heading estimates remarkably similar to the data. I have also shown that this angle can be calculated directly from the 2-dimensional image velocities of points in the image. Thus the visual system does not have to calculate the actual path of motion of the observer to estimate this heading.

Many questions remain to be addressed with computational modeling. First, how does the visual system incorporate information about eye movements into the computation of heading? It must somehow convert information about the speed and direction of an eye movement into information about the resulting motion of the visual image. It must then take this information into account when calculating heading. Second, how does the visual system deal with objects that are moving relative to the rest of the scene? The presence of these moving objects complicates the problem of judging heading even in the case of pure translation. Hildreth (1992) has proposed one possible model that can accurately calculate heading in the presence of moving objects. In the future, I hope to modify this model to fit our current psychophysical data and to extend it to incorporate ideas generated from our ongoing experiments.

Psychophysical Experiments:

The main focus of my work during the period I have been funded by the Bunting institute has been to design and program initial experiments to measure how well people can judge their heading when other objects in the environment are moving. I have finished developing the experimental system, and started to collect data for these experiments. We are using an Apple Quadra 950 to display our motion sequences. Each sequence shows two or more surfaces defined by random dots that will move relative to the observer. The surfaces move independently of each other so that we can simulate objects moving relative to a scene.

In our initial experiments, we are examining the effects on heading perception of size, speed and direction of a moving object relative to a stationary scene. Most current computational models predict that heading accuracy will decrease as the size of a moving object increases. The speed and direction of the moving object should also have an effect, causing larger errors in heading judgments as the directions of the image velocities generated from the moving object deviate from those generated by the observer motion

toward the rest of the scene. In our initial experiments, we have found that moving objects do have an effect on an observer's ability to judge their heading. The presence of a moving object in the scene biases the heading perceived by the observer in the direction that the object is moving. For example, an object moving leftward will bias an observer's heading perception toward the left. Larger objects tend to increase this effect. Surprisingly, simple models for calculating heading would predict biases in the opposite direction than we are finding in the initial experiments. We have yet to explain the reason for this discrepancy, but future experiments should shed light on the mechanisms for this heading bias.

In the future we will study how these different parameters affect an observer's ability to judge which portion of a scene is moving relative to the rest of the scene. In addition to those parameters stated above, relative depth of the moving and static portions of the scene may play a role in this perception.

Bibliography:

Hildreth, E. C. (1992) Recovering heading for visually-guided navigation. Vision Res. 32: 1177 - 1192.

Perrone, J. A. (1992) Model for the computation of self-motion in biological systems. J. Opt. Soc. Am. A 9: 177 - 194.

Royden, C. S., Banks, M. S., and Crowell, J. A. (1992) The perception of heading during eye movements. Nature 360: 583 - 585.

Presentations Given During Bunting Fellowship:

1. Heading Perception in the presence of rotations: image movement vs. eye movement. Center for Neuroscience Seminar, University of California at Davis. Invited talk. April 7, 1993.

2. Human Heading Perception: Can we actually see where we're going? Computer Science Colloquium, Wellesley College, Wellesley, MA. Invited talk. April 28, 1993.

3. Heading perception in the presence of rotations: image movement vs. eye movement. Center for Brain and Behavior Seminar, Harvard University, Cambridge, MA. Invited talk. May 14, 1993.

4. Human heading perception: Can we actually see where we're going? Bunting Institute Colloquium, Cambridge, MA. May, 19, 1993.

5. Heading perception in the presence of rotations. International conference and NATO workshop on Binocular Stereopsis and Optic Flow. York University, Toronto Canada. Poster presentation. June 23, 1993.

Papers:

Royden, C.S., Banks, M.S. and Crowell, J.A. (1993). Perception of heading in the presence of rotations. In preparation for Vision Research.

Influence of the Bunting fellowship:

The Bunting Science Scholar's fellowship has truly been a godsend for me, enabling me to continue my scientific career at a time when I am constrained by personal circumstances and limited funding options. I have chosen to extend my time as a post-doctoral fellow for both personal and career reasons. In terms of my career, I made a large change in fields after I received my PhD in Neuroscience. I wanted to have extra time in which to learn the details of my new field and to establish myself in that field before starting a job as an assistant professor. On the personal side, I have a young child, and the postdoctoral fellowship allows me to concentrate on my research and the demands of caring for a small child without the extra responsibilities of teaching and committee work brought on by a tenure-track academic position. I also have a spouse who is completing his medical training. Ideally I would like to look for a permanent academic position at the same time as my husband, so we can arrange for jobs in the same place. The Bunting fellowship has allowed me to continue working as a postdoc in my chosen field at a time when I have limited options for other types of funding. I believe that many other women in science face similar personal circumstances at this time in their career, and fellowships like the Bunting Science Scholars fellowship will help these women manage the difficult task of balancing career and family, thus reducing the attrition rate of women in science.

The Bunting Institute is remarkable in that it not only provides funding, but it provides a place where women scholars can meet and learn from one another. I found that my association with this group of outstanding women from all fields of endeavor was incredibly inspiring. I also received considerable emotional and personal support from these women in a way that I have not experienced elsewhere. I find that, as I finish my year with the Bunting, I am happier and more confident about my career, and I know this is due to my interactions with the other Bunting Scholars. For encouraging women in science to continue their careers, and allowing them to manage the difficulties of career and family, the Bunting Science Scholars fellowship is a gem, and I am grateful that I have been able to have this experience.

August 1993

To: Linda Eisenmann
From: Janet Talvacchia
Re: Year-End Report for ONR

PROJECT SUMMARY

The project was a study of the SU(2) Yang-Mills-Higgs equations on $\Re^3$ with arbitrary positive coupling constant. The Yang-Mills-Higgs equations on $\Re^3$ are a system of 2^{nd} order non-linear equations:

$$*D_A * F = [D_A\phi, \phi]$$

$$*D_A * D\phi = \frac{\lambda}{2}\phi(|\phi|^2 - 1)$$

Here the variables are A, a connection on a principle SU(2) bundle and ϕ a section of the vector bundle su(2) $\times\Re^3$ called the Higgs field. D_A is covariant differentiation and F is the curvature of A, $F = dA + A \wedge A$. These equations can be viewed as the variational equations of the action functional:

$$\int_{\Re^3} d^3x|F_A|^2 + |D_A\phi|^2 + \frac{\lambda}{4}||\phi|^2 - 1|^2$$

The solutions of these equations are called monopoles and the configuration space decomposes into homotopy classes of maps indexed by degree or monopole number.

The outcome of the project was a proof of the existence of a non-minimal critical point with monopole number zero of the Yang-Mills-Higgs functional; that is, the existence of a saddle point solution in the zero monopole class for this system of equations. The technique of the proof involved extending a min-max approach developed by C. Taubes to apply to this system. The first step was to prove the existence of a configuration that achieved the minima of the action over all non-zero monopole classes. Using this minima, a trial loop on which to begin a min-max procedure was constructed that had an appropriate upper bound to insure convergence. It was then shown that the min-max procedure converged in this context. In addition, an investigation of solutions in the non-zero monopole classes and the nature of these solutions was begun and work on this is ongoing.

The Bunting Fellowship was invaluable in helping the investigator expand her research from more classical differential geometry to gauge theory. The year at the Harvard Math department provided close contact with experts in gauge theory and the weekly seminars there fascilitated quick entry into the main currents of research. Support from the Bunting Institute made full and undistratcted immersion in the new research area possible. In addition to the above work, the investigator has begun work on the moduli spaces of self dual Yang-Mills-Higgs connections on the compliment of a knot in $\Re^3$ and a study of the Skyrme model using the min-max techniques mentioned above.

PUBLICATIONS

Sibner,L. and Talvacchia,J.," The Existence of Non-minimal Critical Points of the SU(2) Yang-Mills-Higgs Equations With Arbitrary Positive Coupling Constant", submitted to *Communications In Mathematical Physics*.

TALKS

January 1993, Bunting Institute, Radcliffe College
February 1993, University of Connecticut , Storrs
March 1993, Wellsley College
March 1993, Bowen Public School, Newton, MA (Visiting Scientist Program)
April 1993, American Mathematical Society, Eastern Section Meeting,Washington,D.C.
May 1993, Harvard University

Aug. 11, 1993

TO: Linda Eisenmann
FROM: Cheryl A. White CW
RE: Summary of year's work

During the year I spent as a Bunting Institute Science Scholar, supported by an Office of Naval Research fellowship, I carried out research on development of the mammalian visual system at M.I.T. Specific achievements were publication of a paper in the Proceedings of the National Academy of Sciences and publication of a short communication in the Society for Neuroscience Abstracts. In addition, I presented research papers at the 1992 meeting of the Society for Neuroscience in Anaheim, CA and at the International Congress on Eye Research in Stresa, Italy. Finally, I gave a one-hour colloquium on my work at the Bunting Institute.

The ONR fellowship allowed me to complete an immunocytochemical study of the development of an inhibitory neurotransmitter in the visual thalamus. This work complemented earlier work of mine on the physiological development of the visual thalamus and was carried out in part by an undergraduate research student at M.I.T. whom I supervised. The student, Udaya Liyanage, will present our work at the 1993 annual meeting of the Society for Neuroscience in Washington, D.C. In addition, I am currently completing data analysis for preparation of a manuscript on this work, to be submitted to a neuroscience journal in the fall.

As you know, I have decided to expand my work to include studies of human development of the nervous system. To be able to do this and to become involved in health care of children with neurological disorders, I will begin medical studies at Harvard Medical School this fall. Undoubtedly, my participation in the Bunting Institute was helpful in my successful application to Harvard and other excellent schools. Indeed, during interviews, I was specifically asked about my association with the Bunting Institute and the research I was carrying out under the ONR fellowship. Completion of medical studies will greatly enhance my ability to carry out research on important issues in neural development. Thus, the Bunting Instititue Science Scholars program will have played an important role in my development as a scientist and as a contributor to the nation's health care system.